

# Renewable Energy

Changing our  
energy future  
with Renewables





The Solar Energy Technologies Program at ORNL is focused on developing a low-cost approach for efficiently collecting and converting solar energy into useful electricity in order to ensure that America's energy portfolio supports a cleaner environment, stronger economy, and strengthened national security. ORNL is helping to meet these challenges by conducting aggressive research, development, and deployment of solar energy technologies and systems to significantly reduce the cost of solar electricity by 2015. The Solar Program's expertise includes photovoltaic material synthesis, characterization, and processing, as well as solar tracking devices, sensors and controls, electronics, and systems integration.

## Technology Development

ORNL's Center for Nanophase Materials Sciences, the High Temperature Materials Laboratory, and the Spallation Neutron Source house the world's highest-resolution electron microscopes as well as unique capabilities for using neutron scattering to characterize photovoltaic materials. ORNL recently established the Center for Advanced Thin-film Systems, which contains a suite of optical and electrical characterization equipment specifically focused on solar cell research.



*Optical characterization specifically focused on solar cell research*

## Materials

Thin film technologies, such as amorphous silicon, CIGS (copper, indium, gallium, and selenium), and CdTe (cadmium telluride), offer the cost advantage of using less solar-active material. ORNL is exploring innovative technologies for the next generation of solar materials, involving unique nanostructures and organic materials.



## Systems Integration

ORNL's System Integration group is exploring wide band gap materials that are more reliable and have longer lifetimes than the current technology. They are also exploring the integration of solar technology into a "smart grid" system.

## Volunteer State Solar Initiative

The Volunteer State Solar Initiative consists of two primary components: the West Tennessee Solar Farm and the Tennessee Solar Institute (TSI). The 5 megawatt solar farm, located near Brownsville, TN, will be one of the largest utility-scale solar power facilities in the Southeast. TSI is a center of excellence between the University of Tennessee and ORNL that brings together scientists, students, policy makers, and industry partners to generate transformative changes to the field of solar-generated energy production. Learn more about the Tennessee Solar Institute at <http://solar.tennessee.edu/>.

## Market Transformation

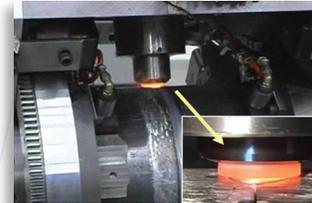
Through interactions with the Solar America Cities, ORNL provides technical and analytical support to prospective cities to tackle an array of technology barriers and opportunities with a limited set of decision makers. The Solar America City of Knoxville is installing three highly visible solar systems in strategic locations. Knoxville and ORNL as a team are becoming a leader in the state outreach efforts through working with the solar community, utilities, and TVA in addressing policy and financing issues and maintaining a strong solar employment base.



The ORNL Wind Program works to improve the environmental performance of wind systems. ORNL expertise provides technical knowledge to Institute of Electrical and Electronic Engineers Wind Power working groups that disseminate information through publication, panel sessions, and tutorial sessions to utility engineers, wind developers and wind plant designers, which helps to lower cost of integration and interconnection while increasing operational efficiency of wind power plants.

## Materials and Components

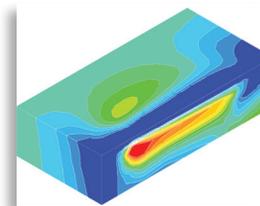
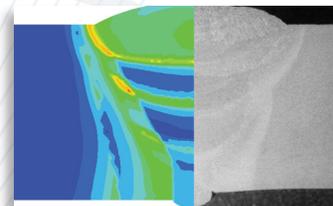
- Materials testing
- Composite materials
- Welding and manufacturing
- Bearing failure analysis
- High temp superconducting



*Friction stir welding of high-strength steel pipe with improved weld microstructure and properties*

## Power Systems Modeling

- Wind export interactions with the grid
- Wind hydro modeling
- Geospatial and information systems for energy applications, planning, siting, permitting, and analysis of generation and delivery



*Advanced weld modeling for controlling residual stresses and improving weld fatigue life*

## Power Conversion

- Generators
- Power electronics

## Power Systems Integration

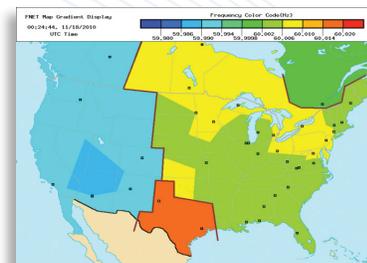
- Protection and relaying
- Industry standards and utility outreach

## Environmental

- Ecological risk assessment for siting

## Supply Chain Development

- Michigan economic development





ORNL's Bioenergy Program is bringing together teams from across laboratory disciplines and the country to research biofeedstocks, feedstock logistics, biorefineries, product delivery, and the sustainability of the supply chain. Its goal is to enable the U.S. national vision of large-scale sustainable production of biofuels, bioproducts, and biopower to enhance energy security, reduce greenhouse gas emissions, and promote the rural economy.



*Switchgrass is a common bioenergy feedstock ORNL researchers are studying*

## Biofeedstocks

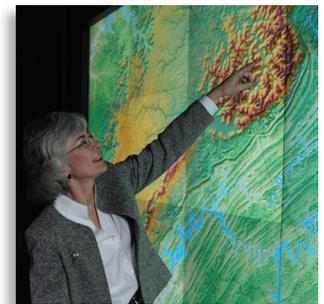
Combining cutting-edge genomic, computer, and image technology, the ORNL BioEnergy Science Center is exploring the fundamental biology-controlling cell wall construction and chemistry.

## Feedstock Logistics

ORNL agricultural engineers evaluate and model the changes in bio-feedstock qualities as they move along the supply chain, as well as the energy cost and resources used.

## Sustainability

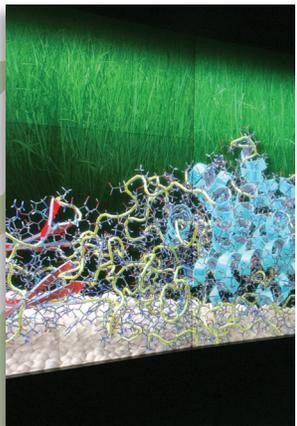
Drawing on ORNL's historic environmental studies on bioenergy crops, the Center for BioEnergy Sustainability was opened in 2009. The Center uses science and analysis to understand and promote the sustainability (environmental, economic, and social) of bioenergy production and distribution and serves as an independent source of the highest quality data and analysis for bioenergy stakeholders and decision makers.



*Land use information helps determine best placement of bioenergy crops to achieve greatest environmental and economic benefits*

## Biorefineries

ORNL biorefinery-relevant research includes basic research to understand the genetic control on enzymes that breakdown cellulose.



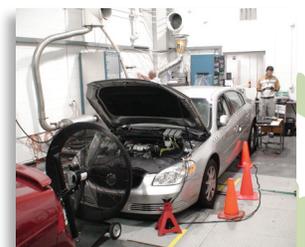
*Visualization showing a cellulase enzyme in action on a cellulose surface with switchgrass in the background*

## Product Delivery

ORNL is applying its rich history and expertise in both transportation and electric grid research to evaluate the delivery elements of the bioenergy supply chain.

## End Users

ORNL researchers who specialize in fuels, engines, and emissions are examining various biofuels and their impact on engine performance, emission controls, general vehicle performance, and material compatibility issues related to storage tanks, pumps, etc.



*Intermediate blends testing at the Fuels, Engines, and Emissions Research Center*

## Information

Through a variety of formats and technologies, ORNL provides relevant, easily accessible information essential to effective policy development and support of the national bioenergy industry.



ORNL's Geothermal Technologies Program conducts research and development to support enhanced geothermal systems whereby water is injected into the ground and heated by subsurface fractured rocks. ORNL has expertise in geo-chemical analysis, materials in extreme environments, downhole tools and system modeling. This expertise has helped many building owners develop and implement ground source heat pumps cost effectively through optimal integration to their facilities.

### Materials For Drilling Applications

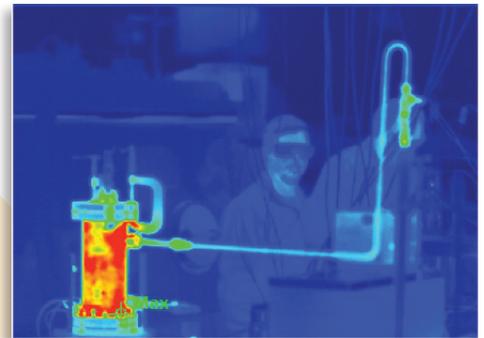
ORNL is performing research to reduce the corrosion and wear of steel tool heads and thereby protecting the integrity of the attachment of the bits to the head.



*Wear-resistant stainless steel coatings and bits for geothermal drilling*

### Alternative Fluids

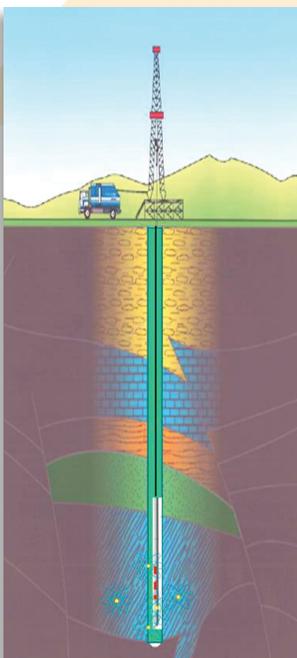
ORNL is identifying and testing new geothermal working fluids leading to improved plant efficiency. This will allow successful exploitation of low temperature wells, increasing the options available for geothermal energy use in more sites across the country.



*Densimeter for evaluating PVT curve (ORNL)*

### High-Temperature Downhole Tools

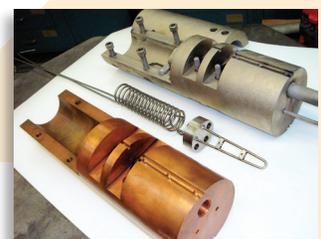
ORNL is performing both feasibility and design studies for a high temperature downhole tool that can measure the porosity, lithology (mineral composition of formation), and density profile of geothermal wells as a function of depth.



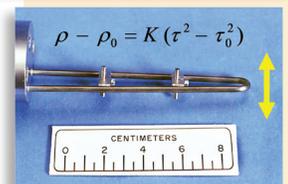
*ORNL vibrating tube flow densimeter for bulk fluid mixtures*

### Modeling and Analysis

ORNL researchers are improving predictive models of fluid-solid interactions in porous materials to impact Enhanced Geothermal Systems at the stages of site selection, reservoir creation, stimulation, and sustained operations.



*ORNL high-temperature VTD operating to 400 °C and 1000 bar. The density is proportional to the square of the vibration period.*



$$\rho - \rho_0 = K(\tau^2 - \tau_0^2)$$

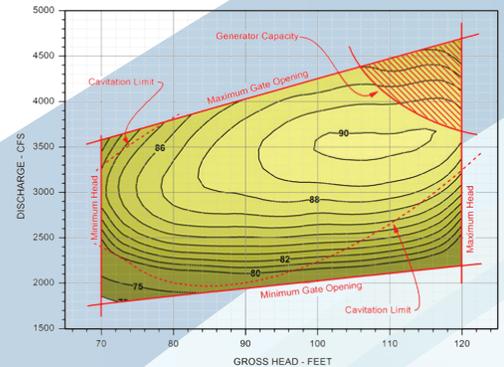
The ORNL's Water Power Technologies Program is composed of an interdisciplinary research team addressing technological hydrological and environmental issues related to both developed and emergent hydropower technologies within four major areas: Conventional Hydropower, Environmental and Ecological Impacts, Marine Hydrokinetics Research and Development, and Grid Interconnection. Expertise of the team members includes engineering, aquatic ecology, hydraulics, modeling and economics.

### Conventional Hydropower

- National Hydropower Asset Assessment and National Resource Assessment - Assess the condition and performance of all U.S. federal and non-federal hydropower plants, equipment, dams, diversions, reservoirs, non-powered dams, pumped-storage facilities and their connectivity in river basins. Develop and maintain an up-to-date U.S. hydropower integrated dataset. Evaluate and prioritize the potential to increase power production by converting non-powered dams and to add new pumped storage facilities to the existing U.S. fleet.
- Hydropower Advancement Project -Apply systematic assessment to existing hydropower facilities for implementing best practices to lower cost and reduce uncertainty of return on investment of operations improvement and equipment upgrades. These activities are aimed at increasing hydropower capacity, efficiency, and environmental performance at existing power plants.



ORNL research is aimed at improving reliability of equipment such as the flow control gates.



ORNL decision support research will help operators ensure that turbines operate within regions of maximum efficiency.

### Environmental and Ecological Impacts

#### Conventional Hydropower

- Successful Turbine Passage for Migratory Fish - Better characterization of causes of injury/mortality during turbine passage; Predictions of injury/mortality among untested fish species; Development and experimental verification of models to predict turbine passage survival for different species, turbine designs, and operating conditions.
- Effective Environmental Flows - Characterizing hydropower-altered flow regimes and the relationships between various components of natural flow regimes and environmental benefits; Developing alternative flow assessment methods with more hydro-relevant metrics; Guidance for dam operators and regulators for selecting most appropriate flow assessment methodologies and approaches.

- Greenhouse Gas Emissions – Field characterization of greenhouse gas emissions from hydropower reservoirs in the U.S.; Model estimates of net reservoir emissions; Developing relationships between reservoir characteristics and likely greenhouse gas emissions.

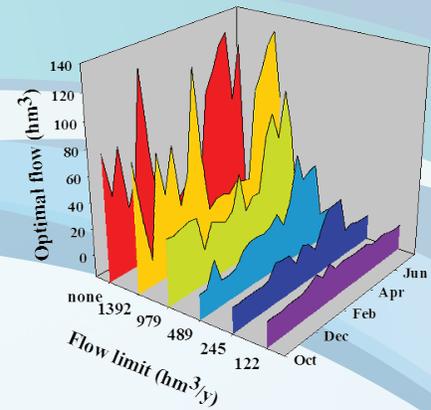


ORNL is assessing greenhouse gas emissions at Douglas Dam, TN.

- Water Use Optimization - Develop an integrated set of models and approaches for optimizing the operational efficiency and environmental performance of hydroelectric power plants.

### Environmental and Ecological Impacts - cont.

- Marine and Hydrokinetic Power - studies on the effects of non-dam hydropower technologies on aquatic organisms and their habitats, including the effects of physical interactions with devices, noise, electromagnetic fields, toxic emissions, and habitat alteration.
- Climate Change - investigations on effects of projected change in climate and their influences on hydrologic variability in rainfall, stream flow, and water use and availability on hydropower production and associated environmental impacts as a result of projected climate change.



ORNL ecological research is aimed at optimizing flows for fish and energy.

### Marine Hydrokinetics Research and Development



ORNL conducts detailed turbulent flow measurements at Melton Hill Dam, TN.

- Expertise in laboratory and field measurements, post-processing and analysis of bulk and mean flow properties of turbulent flows for machine inflow characterization, computational fluid dynamics (CFD) model boundary conditions, and CFD model validation.
- Development of reference models for hydrokinetic resources, including hydraulic properties of resource, hydrodynamic loads, power density, annual energy production, and morphological and ecosystem properties.

### Grid Interconnection

- Evaluating the value of hydropower resources to the grid through examining the power system (market and reliability) needs and the constraint on hydropower resources in providing these services to the grid.



Aerating turbine technology improves tail water quality with minimal efficiency losses.

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